PANEL DISCUSSION FOLLOWING THE THIRD DOD PTTI STRATEGIC PLANNING MEETING

PANEL MEMBERS

Dr. A. Berman	R. S. Day	Dr. F. H. Reder
J. L. Brennan	H. C. Folts	Dr. F. W. Rohde
J. F. Bryant	Dr. J. C. Hafele	Dr. L. J. Rueger
A. R. Chi	Dr. E. Hafner	R. R. Stone
Dr. L. S. Cutler	LCDR C. E. Potts	Dr. G. M. R. Winkler

MR. PARSONS:

In the FSK mode of time marking at Northwest Cape as discussed by Dr. Winkler, is it not possible to increase the time resolution by use of a coded sequence, pulse compression?

MR. STONE:

Were you asking whether it were possible to increase the time resolution from Northwest Cape by a coded sequence? There is a problem there in that when we went on to these stations we agreed not to interfere with communications whatsoever. We are just a little bit bound by what they do. It would be possible, yes, if we were allowed to use some segment of time. In fact, the 20-millisecond pulses we have can be used just by the fact that they are repetitive at 20 milliseconds.

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I left the Bureau of Standards some years ago and as a user of time announcements on the standard frequency signals, I have found a shortage. I noticed here in the backroom that CHU is being used to get some type of time response. The signals are too weak nationally and we have lost a lot on the East Coast. I'm wondering if the people charged with disseminating time are going to give us back our nationwide NBS-transmitted coverage of time signals on the East Coast? We have the problem of data acquisition which must be retrievable by non-trained personnel and I see a loss in the nation's scientific capabilities due to the lack of the time announcements on standard frequencies.

DR. WINKLER:

I would like to answer that and ask that Mr. Gatterer also comment. I think NBS is very much aware of some of these difficulties. The following steps have been taken: one, within the new format of WWV there is an announcement every minute instead of every five minutes. I think the new format is a much better one, much more useful; two, NBS has, of course, made a great effort to accomplish a nationwide television time transfer. Considering the fact that almost everyone has a television set, it will be quite easy to get time--without any sophistication--to at least the precision of WWV, provided that some safeguards are installed to prevent very large propagation changes. But there is no question in my mind that it will be a valuable service. Also Mr. Gatterer has reported on the experimental satellite dissemination of the WWV format, which according to our experience in Perrine, Florida, is a fine system. With a little bit more instrumentation, I think what Mr. Gatterer described would become a useful system. My main concern is that it might provide justification to shut off the remaining high-frequency time signals; I am concerned about that because they are still, I think, the backbone of timing. There are additional things I have been thinking. For instance, you can receive WWV here on the East Coast at practically any time of the day; you just have to remember that the frequencies will be quite different from what we used to receive here in the local area. I think people have not realized that they are still listening at 2-1/2 megacycles instead of at 15 or 20, and at these frequencies the service is very clear and reliable. At the Naval Observatory the times of arrival change at those frequencies only by 100 microseconds from day to day, unless there is severe interference on the air. Also, CHU is a valuable additional service available here on the East Coast. The only reason it is used here is that it comes in more clearly in this noise-infested environment of a major laboratory; CHU is much closer, of course. Also, there is the new, very high-powered station, NSS: Hopefully, when it comes back on with something like a megawatt radiation we will have the time signals on VLF as we used to. The deficit of service you mentioned is of grave concern to us also and we will try to provide some additional services. But I think that in summarizing, some of these systems which are in development and have been mentioned will help to improve the situation. Mr. Gatterer, would you care to comment?

MR. GATTERER:

I think you covered the subject adequately, but I would like to add that after a suitable evaluation, we may be much more optimistic about the accuracy of the television time transfer than you thought possible. With regard to the satellites, I add only that it appears to me a certainty that there will be, from now on, a good, usable satellite service available in the United States; in particular, the experimental ATS satellite service is available so cheaply that anyone who really has any problem receiving WWV has no reason to go without time right now.

DR. WINKLER:

I would like to add one more comment and that is that one should not underestimate some of these difficulties in operating a normal station. If operators have trouble getting WWV to milliseconds--and I know many who have--then the trouble will be compounded with the new systems; they will necessitate more intensive training, there is no question about it. You may underestimate that. The application of much larger corrections will force everyone into that when in fact most people today don't bother about receiver delays, or propagation delays of 8 milliseconds or things like that. I think one should be optimistic but also should be prepared for the additional training that will be required to use some of these more sophisticated methods.

MR. GATTERER:

It has been my experience that WWV is receivable virtually everywhere in the United States. There are some people who have some trouble; for example, down in Florida, in the Miami area, they use a half rhombic antenna to receive it, but they need only one because WWV is distributed by telephone in the Miami region, so all they have to do is get a telephone to hear it without even buying a receiver. The same is true of course in Colorado, in Los Angeles, and here in Washington, D. C. We are becoming increasingly aware that there are very simple things we can do at NBS to make our "nuts-and-bolts" service more readily available to those who need it.

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I think there is one point that perhaps I didn't make clear: this is an unmanned, automatic data reception center. No one is there to tune the receiver and the background of time information is necessary on the recorded information; therefore you are limited by the problem of multiple frequency selection on the receivers. The basic fact is that we'd like to see the same kind of service we had before they moved WWV to Colorado.

DR. WINKLER:

In this case, why don't you receive WWVB? WWVB can be received very well as it has a continuing time code and all you have to make sure of is that in your initial installation you install your antenna in a way that will reject or greatly reduce the interfering MSF signal. But WWVB can be received anywhere in the continental United States with plenty of signal strength. I recommend you look into that.

MR. GATTERER:

I'm sorry I can't quite agree, because there are some null spots that give some people a lot of trouble. I can't be quite as optimistic as you've just been, but even in the case of individuals that are unfortunate to be in a null spot, we are broadcasting on the satellite the NASA time code that is broadcast on WWV.

DR. WINKLER:

The satellite service is not available on a 24 hour a day basis, which you seem to require. Am I not correct that these null spots to which you refer are multimode interferences which are not too very far away from Ft. Collins?

MR. GATTERER:

I am thinking of some troubles I've had in receiving it in Washington, D. C. Obviously you are a better authority on that than I am.

DR. WINKLER:

Here in Washington it comes in very well. No problems, if you only want the time code. High precision phase tracking is where the problems are.

DR. RUEGER:

The question was raised as to what the Transit navigation satellite system might do about the time. I want to make it perfectly clear that there will be absolutely no interruption of the accurate service of the system throughout the time changeover. The ground navigation programs use the satellite time as broadcast and the position of the satellite is in terms of the time carried aboard the satellite. On the other hand, this change in frequency did cause us some concern and the solution has been that we will change over to the new UTC time system and we will follow leap seconds. The only real problem arises at the changeover period when we want to predict the orbit in the new time frame. This means we will ride on a longer prediction--for one to three days--and the accuracy of the system could be degraded by thinking in terms of using it fixed-site-for-survey for the three days around the change of the year. On the other hand, the accuracies required for service at sea are easily realized by the prediction of a longer period of time. The change itself has not been issued. It will be published to all users in sufficient time so thay can take account of it. But we expect that all satellites will be on the new time system within three days before or after the time change.

MR. LIEBERMAN:

Since this was billed as a planning conference I wonder if we could discuss the real need for real time, for PTTI. We've skirted it, we've talked about what we've done, but we're just not climbing a mountain because it's there. I wonder if we could address some real need in the immediate future and what we see in accuracy required.

DR. WINKLER:

If I understand, Mr. Lieberman, you want to find out who needs something that he can't get today.

MR. LIEBERMAN:

The question always comes up with communication people and navigation people: Why do we need precise time, to what accuracy? We have put out a questionnaire, but the questions are general and I wonder if we can get into a discussion here of the real need for precise time.

MR. BRENNAN:

Well, I can only repeat what I said this morning: while a basic decision hasn't been made within the FAA on a requirement or national standard collision avoidance system, our prime efforts have been devoted to a synchronized system--time frequency system--and the requirements as evolved in the ATA's technical working group call for a ground synchronizing network in which each ground station is to be within plus or minus a half a microsecond of a master time, which hasn't been decided on yet either. So I can only say that if in the future the decision were made to select the time frequency system as a CAS, then a ground station network would be needed and therefore we would need PTTI. The methods by which the ground station would be synchronized to a master time are still conjectural. We have heard various methods described and we should take a look at them all and try to pick the most efficient, optimum system.

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I would like to turn Mr. Lieberman's question around and suggest that generally speaking one develops something new and then finds ways of using it. I recall the days of the Laser, which was often cited as a "solution in search of problem". I think this may be, to a very large extent, true of time standards and particularly this example of a collision avoidance system, which wouldn't have been dreamed of had there not been a prospect of very precise timing and some generally well-accepted experiments perhaps ten years ago.

MR. BRENNAN:

I think that's true.

DR. REUGER:

Navigation happens to be one of the frontiers opened up by precision time and frequency. It wouldn't have been possible many years ago to have a satellite with the quality of oscillator and timing we now have. I forgot to mention that we do have a problem with satellites in orbit in the Transit Program--we can't change their frequency; but fortunately the system was devised to have the time and the frequency as independent variables and we can take care of the time independently. In the future, the quickness with which we can get a position fix has to do with the time synchronization and using technologies other than Doppler, primarily the ranging type systems. You heard that the Loran-C system has hundreds of nanoseconds resolution. If I understand some of the aircraft people's needs and desires, they would like to have a 50-foot resolution on a ranging system. This represents a timing system that has significance, either relative or absolute, to 50 nanoseconds. And these are things I think we can't do today.

DR. ROHDE:

I'd like to mention also that in navigation or in survey and positioning techniques very precise clocks are highly desirable. If we had clocks available with one-or-two orders of magnitude more accuracy, the Long Range Precision Determination System (LRPDS), which I discussed yesterday, would automatically be a one-ranging system and calculation and data reduction and many other things would be much easier. The same would apply to the Defense Navigation System where the Army is the potential user for positioning. So I would say there is a need for more advanced clocks which are field worthy rather than say there are no requirements.

DR. WINKLER:

I would like to go back to some of the basic philosophies in the use of time frequency. I think in each case the primary question of systems concept would be "why do we want to introduce clocks?" For example, we have a television system that is a synchronized system: every user locks onto the synchronization signals on the air on the same carrier from the same transmitter providing the service. In this case, hypothetically, we would say if that is a candidate for a true time-frequency modification, why would we like to have a clock in the receiver? The answers I see in those systems which have turned towards the application of clocks have been these: one, precise one-way ranging measurements, distance measurements, that are one-way because you don't want the user to retransmit; two, the collision avoidance system, where you are forced to communicate on just one frequency but have many, many users who have to operate on a time-sharing basis, the same requirement you have in channel packing; three, you want to use a clock because of its anti-jam capability, because you know what the other side is doing without having to receive it continuously. In my view these are the main applications. When it comes to making such precise measurements as 50 feet (which is 15 meters, I think) it may be useful, in the system's conceptual development stage to ask if it is necessary to have this in the form of a worldwide system. If not--to do it regionally,

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if a regional system is sufficient--you suddenly have no problems whatsoever and can get the system into operation immediately. I am suggesting these alternatives because I think we ought to keep our minds open and we have here, I'm sure, quite a few people responsible for the development of systems concepts. It is necessary to intercompare other possibilities. Considering the problem of many users operating, necessarily, on the same channel, one can make a virtue out of the problem by correlation. The same thing is being done in communications where you can superimpose several different channels on one channel by using spread spectrum methods, as Mr. Stone has mentioned. In addition, his timing application can also be superimposed on existing communication channels so that they don't interfere crosswise. We have heard another presentation concerning the same principle. It can be extended, given a sufficient signal-to-noise ratio of course, to hundreds or thousands of different channels. So there is a variety of ways out, and I think it may be a mistake to discount all of these without really investigating them on their merits. My greatest concern is that maybe some of these 10-foot or 50-foot precisions may have overlooked the substantial difficulties of propagation time effects, geodesy uncertainties, and things like that. There are really substantial effects which are at least of the same degree of difficulty as the unavailability of clocks which will keep one part in 10^{15} for a year.

DR. REUGER:

There is one I think you may have left out, which has to do with the LORAN-C type of operation on a range-range basis. It is very hard to keep a clock to the correct value over very many days without some kind of reference.

DR. WINKLER:

That is also not 100 percent correct. In the Journal of Navigation, I think of last year, there is a description of an iterative method by which you first get your hyperbolic position and then you get your time and you find better solutions in using the circular geometry. You bootstrap yourself into greater and greater precision and you don't need time from the beginning at all.

DR. REUGER:

That's very fine if you are in a favorable location. If you are in range of only two stations, I do not think that system works.

DR. WINKLER:

Yes, I agree.

DR. CUTLER:

I'd like to just make one comment in regard to worldwide time synchronization. We're rapidly approaching the point in our accuracy (or stability) and measurement capabilities where we are going to run up against a fundamental limitation: the earth is rotating with respect to "fixed" stars and if one looks at the problem of clock synchronization in a rotating coordinate system--that is, rotating with respect to the fixed stars--he finds that it's impossible to synchronize clocks around a closed path, which encloses the origin of this rotating coordinate system. These are small effects, but nevertheless they are starting to become noticeable. In fact that has a lot to do with Professor Hafele's experiment. I just wanted to make that comment, that this is a fundamental limitation.

LCDR POTTS:

I would like to comment on Dr. Hafele's presentation. I think the real significance--the practical significance--is to make clock comparisons with greater precision than we are doing now, 100 nanoseconds, plus or minus. If we are going to compare clocks which are at different gravitational potentials then we are going to have to apply the principles investigated by Dr. Hafele.

DR. HAFELE:

I would like to suggest something that might be amusing. To bring the effect out more clearly you could imagine you have a string of cesium beam clocks on the surface of the earth around the Equator; line them up every mile or ten miles and start synchronizing them by the Einstein Synchronization Convention, by sending a light beam to the next clock in the row, reflecting

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it back, then assuming the time it takes for the light to go from one clock to another and back is just twice what it takes for light to go from one clock to the other clock. By the time you get the string synchronized all the way around you find that the last clock in the string is not synchronized with the first clock, and the difference is 240 nanoseconds or a quarter of a microsecond, considerably larger than the kind of synchronization we've been talking about here. So in fact this is at the Equator; as you go to higher latitudes the circles get smaller and the effects get smaller, but any closed loop on the surface of the earth in principle cannot be synchronized using that synchronization convention. There will always be a little bit of difference; it takes light a different amount of time to go around the loop one way than it does around the other way, so in principle it is not possible to synchronize the clocks exactly. This is a question I think the world community will have to decide: How shall we synchronize our clocks? If we synchronize them according to Einstein's convention, there will always be these discontinuities in the synchronization. In 10 or 50 or 100 years we may come to the point where we set up a coordinated network of times over the surface of the earth or choose another synchronization method that would eliminate these discontinuities in the synchronization. Of course you can calculate, knowing the rotation of the earth and the location of each clock on the earth, how the synchronization should be adjusted so there would be no discontinuity.

MR. PARSONS:
The use of LORAN-C is not universal. If one has to observe an unpredictable event or even a controlled event over which he has some uncertainty as to its time of occurrence, we will be a long time getting to better than microsecond accuracy I should think, if we are now talking about times and coordination in the realm of 10 microseconds. To me this amounts to a problem of looking at time resolution elements for an unpredictable event involving perhaps, as it stands today, 50 million resolution elements, the

synchronization of stations is that poor. Now if it got down to 5,000 or 50,000 resolution elements, I'd still have a problem. We're talking here about uncoordinated time and it's just not being effective. Mr. Folts, in his efforts in the DCA, is trying to get a coordinated viewpoint on what the requirements are. Hopefully, we'll get ten microseconds throughout the world--hopefully we'll get one.

MR. WATSON:

I have an observation relative to timing needs versus the user's operation that ties in somewhat with Dr. Hafele's comments on time gradients and the concern over time shear. Basically the user of long-haul communication links or long-time transfer travelling clock type applications may have to be content with a time resolution, a communication event recognition, that is defined by the anomalies or the variation or the noise in his communication media. That, basically, will set his timing requirements. In the case of collision avoidance we can take a time gradient over the United States that is time shear in a local area, that we could administer without two ground stations in an immediate area and exhibit a time shear to airplanes coming into that area. We could think of time for the CAS system or time for any of these other systems having controlled gradients staying away from time shear. Say that we have a hard and fast master, a master for reference to the CAS system; then within the United States, I think, time can undulate or be a potential level as long as the gradients within an immediate area do not present shear to the user.

I don't want people to be overwhelmed with this number of plus or minus a half a microsecond. I think that within the immediate area of two ground stations having access to a single airplane, we're thinking in terms of the plus or minus one half a microsecond. But I think that the West Coast and the East Coast can be as potential levels operating as a membrane of time.

DR. REDER:

I have a question for Professor Hafele. Will you run into the same problem you have when you line up the string of clocks around the Equator if you line up the string of clocks along a meridian?

DR. HAFELE:

First, I'm thinking of the ideal case where the surface of the earth is equivalent to the average sea level so that we don't have altitude problems changing the rate of the clock; and I am assuming we have the ideal standard clock, something like an ideal cesium clock, which has an intrinsic frequency that can only be varied by the two relativistic effects. If you have a string of clocks in a great circle going around the poles, you can use Einstein's Synchronization Convention along the latitude. The speed of light in a rotating system is different with the rotation and against the rotation and that's what causes the discontinuity in the synchronization. But crosswise to the rotation it doesn't matter which way you go, so if you synchronize the clocks around the poles the last clock will indeed be synchronized with the first.

DR. REDER:

How would it be if we plaster the whole earth with cesium standards both along the meridian and along the Equator and take parallels and then synchronize all the clocks along the meridian to the ones on the poles?

DR. HAFELE:

If you set a clock at the pole and let that be the master and synchronize along the meridian you will find that along the latitude lines where you go, say, from Washington to Los Angeles, those clocks will not be synchronized, they will not be in perfect synchronization. You defined your synchronization procedure -- there's ambiguity in the synchronization, there probably are some more facts. Fortunately the earth doesn't turn all that fast, so we're only talking about, at most, a quarter of a microsecond. But you're right, that would be a different synchronization procedure and if you started at the pole and synchronized down then as you went from one meridian to the next, they would not be synchronized.

DR. CUTLER:

Just another couple of comments along this same line. No matter what synchronization technique you assume to use you will find it is inconsistent in a rotating frame of reference. For example, if you tried to synchronize by carrying a clock, and tried to synchronize each clock as you went by, you'd find the same sorts of results as you would with the Einstein convention. Also, if you carried a clock along a meridian so that it crossed the poles, you would find that as you closed the loop there the results would be consistent. Everything hangs together and you get into trouble whenever you enclose some component of the rotational axis.

LCDR POTTS:

It seems this discussion has circled around a problem which is going to crop up in the future; the problem which was tackled last year at the meeting of the Consultative Committee for the Definition of the Second. That was the specification of an origin for an international atomic time scale, something which is extremely difficult. First of all you'd like the location to be accessible, so the center of the earth is obviously not convenient; it's convenient mathematically but not practically. Then, from the point of view of space travel, the center of the earth is not as convenient as the center of the sun, which is even more difficult to get to. This is an important consideration and will have to be tackled in the future.

DR. WINKLER:

I don't think it is. You can always place a reference point on the pole, and on the pole you wouldn't have any difficulty except with the temperature. But I don't think there is a problem because you just have to specify one location to which you refer all operations.

DR. HAFELE:

I think there is a solution to the problem: not using Einstein's Synchronization Convention. We simply choose a synchronization convention which gives all clocks being synchronized no discontinuities. There's nothing wrong with Einstein's convention, it just causes discontinuities in the synchronization. If you choose a convention that's compatible with the particular angular rotational speed of the earth, then they'll all be synchronized.

DR. HAFNER:

This is a very interesting subject; however, for practical applications, I don't feel it is going to be very important in the future. For the practical application of timing we are concerned about two different things , one being the synchronization of a rather large communications system; here the nanoseconds are not terribly important. For navigation and position-finding, the position determination systems--the really high requirement appears to be 10 nanoseconds or less; however, here we are not talking about very long distances either, and there will be no conflict between systems which are worldwide synchronized to, let's say, half a microsecond and having local synchronization to a much higher degree. The emphasis here is that even in the future we are not going to be very much troubled. However, as far as the requirements of stability are concerned, if we are thinking of one-way ranging and the applications existing in the Army, the size of the equipment that is going to be used in the LRPDS and the size of frequency standards that have the stability better than a part in 10^{11}, are in no measure comparable to what is in existence now. At the present time you can't put the cesium standards on a man's back and this is what the Army is going to need, frequency standards that can be put on a man's back if the one-way ranging systems come to fruition.

MR. WILCOX:

In geodesy we worry a great deal about polar motion, nutation, precession, and I'm wondering, since we are talking about time and mean solar time, how will all this be when we develop that observatory on the pole. I'm sure that sounds like a very nice solution to a light problem, but it's a very serious problem to a geodesist.

DR. WINKLER:

I'm not sure that I understand the full context of the question. You are concerned with improving XY coordinates of the pole.

MR. WILCOX:

My main problem is that in our computations in geodetic astronomy we have to worry about the nutation of the poles and I'm wondering if, first finding the North Pole would be a problem and second, once we found it, would our International Latitude Service tell us we had a wobble since we have a cyclical process of nutation and every 26,000 years we precess? I'm wondering if this will be a problem in terms of this half a microsecond.

DR. WINKLER:

No, we are talking about clock time on one hand and astronomical time or UT-1 on the other. There is no link between these two except the coming 1-second step and the corrections bringing you from the time signal to the clock time you need. But to understand your worry in a larger context, the Naval Observatory is well aware of the need to improve the polar coordinates and the evolution of the UT-1 determination. To place an observatory on the pole is something we have quite actively investigated, and we may yet do it, but there are horrendous difficulties. If you put it on a piece of ice it will drift across the North Pole and you really don't have the stability to measure .01 second of arc. If you go to the South Pole there are other difficulties, among them that the ice is still moving at a speed of 19 meters per year and we are here trying to measure decimeters expressed in angular resolution. So the problem you are touching on is really an astronomical, geodetic, geophysical problem and is not directly connected to the questions with which we are concerned in this conference. But I think it will be of interest to a smaller group and would like to have more private discussions with you on that point.

MR. CHI:

I would like to concur with the statement made by Mr. Lieberman. I think this is probably a good opportunity for us to find more applications in light of the fact that the present funding is low and many people who are working in the field, particularly in frequency and time, will need justification. If we could classify those who might need from 1 microsecond on down and maybe 1 to 10 and 10 to 100 -- if we could only find out where you need it and what you need it for--it probably would help us in long-range planning.

LCDR POTTS:

It seems to me one of the most important things is to conserve our government's dollars. One of the ways we can do this is to coordinate the requirements of the users for time. We've heard of a lot of systems described both this year and last year and many of these systems could exist in their own timeframe without any reference to someone else. There is no reason why the CAS system, for instance, has to be referred back to some master clock somewhere; it could have its own master clock. In fact the Bell System is now planning a scheme for its digital communication facilities by which each facility would have its own master. Some people are attempting to persuade the Bell people to change their mind. The consequence of course would be a proliferation of cesium standards. We would have all these little independent masters--master of this, master of that, master of everything, and it would become difficult for users of one service who want to shift to another service, in another part of the world or local community, to coordinate. There are benefits to be derived from using a common time reference or common frequency reference and to this end I would like to see some efforts devoted in this meeting.

MR. LIEBERMAN:

I think most of our discussion here has been devoted to time rather than time interval and frequency. I wonder if we could discuss that in the next two minutes.

DR. WINKLER:

I think what surfaced in the last ten minutes is something like an identity crisis within the PTTI community. Why is the subject worthy of the simplest consideration as an entity and why is it useful for time-ordered systems to be coordinated so they can interface easily with each other? That we discussed last year. I think it is of continuing concern in respect to an element in which our subject area appears--it's clear the simplest one to satisfy is synchronous frequency. You can accomplish what you need by putting standards with great absolute accuracy into each location where you need it. Reference is the cesium atom--wherever you have it. You get it by buying a cesium standard. Depending on your requirements, you may be satisfied to buy a secondary standard which you send to a calibration center regularly. In designing a system of operations one has to weigh costs doing it one way versus the other one. On the other hand you want to standardize, you want to have a few different types in service, you don't want to get examples of all the possible frequency standards. These are the general considerations. The next level would be synchronization. You don't worry about what you synchronize as long as within your communication or within your measurement area you operate synchronized. That is a timing concept. And finally, the third level is to know epoch or date. Some people prefer the term "real time", but the best in my view is simply "date", the time of the day. This is the most difficult to satisfy because it requires absolute accuracy in timing and the adoption of a reliable reference.

MR. FOLTS:

I just want to comment on the project "Music Man". The things we were talking about this morning seemed to get right back to what we are trying to do in our approach to the worldwide distribution and application of precise time and time interval. In communications we have a definite need for not really so much for epoch time or precise time, as much as the time interval, frequency. Another point is that means of getting the time around the world-- it's just another piece of information--can be passed electrically by various means, and obviously a communications system is a means. This can be done with various levels of precision, accuracy and so on. So really we've found that the DCS has two roles in this area. We need to establish something to satisfy our own requirements and this subsystem can also be available to many other users, perhaps saving a redundancy on individual systems that could be tied in together because it doesn't seem to be any more difficult to put them all onto one than it does having each person run by themselves and of course they don't have anything to fall back on either. Mr. Watson of McDonald-Douglas, commented earlier on this grid system, that we must develop a basic system hierarchy which really falls into that concept. Major prime nodal points can be distributed throughout the world and tied-in quite easily on down the hierarchy at varying degrees of accuracy and precision. This is by the means of getting further on down the different media to the requirements of the user you are trying to reach. So this is where it all falls into a hierarchy type of system. In the initial stages of Music Man, we're really just getting rolling into this. We have two committees working right now; the Requirements Committee is really trying to find throughout DOD all your requirements for time and frequency that you are aware of, both immediate requirements and future requirements; we're trying to basically catalog these, yet have it flexible enough where they can keep being thrown in as they come along. The other committee, the Concepts Committee, is really in two parts; in the first part, while requirements are being brought together, we're trying to look through the complete state-of-the-art, all the technology methods, possibilities, and their potentials to bring them into a central plane. Also there is one very important point here - people think they know where they need time and frequency, but I would venture to say that there are an awful lot of applications for a subsystem or use of time and frequency that people aren't aware of where great potential benefit can be gained. Any type of system or equipment that is time or frequency dependent can benefit. You say we only need a part in 10^3 or part in 10^{11} for this particular equipment, perhaps that piece of equipment was developed back when that was all that was economically available. Today, if we can get up into parts in 10^9 parts in 10^{12}, how would the design concept of that equipment be changed, simplified, made more efficient, so on. When we get all this together, then we will try to define a system hierarchy that can solve these immediate requirements and be dynamic and evolve with everything in the future.

MR. GATTERER:
I assume that most people here are aware of the coming special spring issue of the Proceedings of IEEE on the subject of time and frequency dissemination, generation and applications. For those of you who are not, I'll tell you it will be a tutorial issue that will attempt to provide an accurate appraisal of the state-of-the-art and of the state-of-the-practice of time and frequency matters. It is hoped that a particularly valuable section of this issue will be the Letters to the Editor which will give people an opportunity to update information and report on recent research results. For example, Mr. Brennan could make a valuable contribution by submitting a letter on what is new in CAS. Since we'll want the most recent results, the deadline on the letter will be flexible. If you are willing and feel compelled to contribute your observations from recent results, please don't fail to contact Jim Jespersen, guest editor of this special issue.

DR. WINKLER:

I would like to ask each one of the authors, whose contributions we very deeply appreciate, to please add any reference, any additional source of information to any comments made in the written material, at the time it comes around to you for editing. Also, any second thoughts or any additional graphs or anything that will make the book more valuable.